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Meeting the challenges of modelling coupled human-environmental systems - GLP Nodal Office of Integration and Modelling

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Abstract

Modelling land system change using scientific approaches that integrate the human and environmental systems are increasingly needed. Integrated models are dependent upon our ability, not only to understand and describe the systems, but also to couple different modelling approaches. By promoting and supporting the Global Land Project science plan, the GLP Nodal Office of Integration and Modelling has contributed to the international research agenda through events which have brought together researchers from a broad range of disciplines to address the issues involved in modelling coupled human-environmental systems.

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Keywords: Modelling; Global land project; Land systems; Integration

1. Introduction

The Global Land Project (GLP) is a joint research project for the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP). Established in 2005, the Global Land Project builds upon the Land Use and Land Cover Change (LUCC) and the Global Change and Terrestrial Ecosystems (GCTE) research programs of the previous decade. These IGBP and IHDP core projects enabled the scientific community to increase its understanding of the potential impacts of the dynamics of land use change and their consequences Ojima et al. [1]. However, they also highlighted limitations in our understanding of the dynamics of interactions between social and natural

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systems in the context of land change; the impact of human actions on earth system processes and the consequences of these (i.e. the coupled human-environmental system).

Studies have been undertaken on the human-environmental interactions, but the complexities involved remain less understood Liu et al. [2]. The goal of GLP is to measure, model and understand the coupled human-environmental system Ojima et al. [1]. The GLP science plan covers three research themes; dynamics of land systems, consequences of land system change and integrating analysis and modelling for land sustainability (Fig. 1). Focal areas within these themes are decision-making, land use management, the provision of ecosystem services and their linkage to human well being and the vulnerability and resilience of land systems Ojima et al. [1]. The GLP has taken a holistic approach to study these dynamics as complex, simultaneous interactions between societal, natural and mixed processes at various scales. Such an approach requires existing research communities engaged in land systems research to integrate their research and new researchers from a wider field of disciplines to be encouraged to contribute. The Nodal Office of Integration and Modelling was established to assist the GLP IPO in this task.

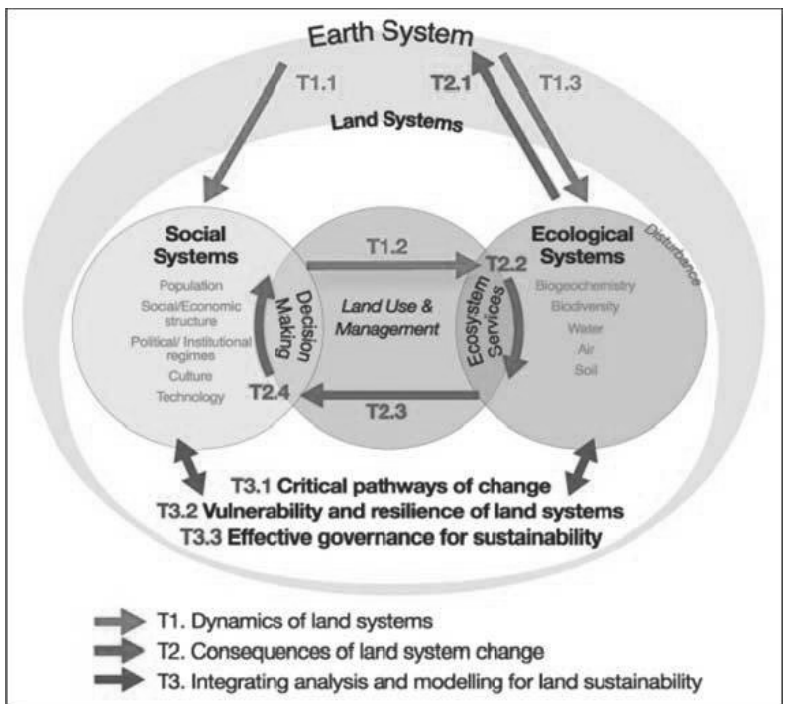

Fig. 1. Analytical structure of the GLP. Ojima et al. [1].

Based at the Macaulay Land Use Research Institute in Aberdeen, the Nodal Office is a joint initiative between the Macaulay Land Use Research Institute and the University of Aberdeen. The aims of the GLP Nodal Office of Integration and Modelling are to; focus international efforts on the scientific aspects of integration and modelling, provide links between researchers for multi-disciplinary studies and publish scientific and policy related material. Since the Office was established it has facilitated events to achieve these aims through a series of workshops.

2. Workshops Facilitating International Exchange

2.1. 'The design of integrative models of natural and social systems in land change science'

'The design of integrative models of natural and social systems in land change science' workshop aimed to i) take a broad overview of where the land change community is today in terms of integrative models of natural and social systems and ii) provide an opportunity for land use modellers working at different scales with different remits and approaches to discuss commonalities and differences.

Participants from nine different countries drew on their own research to discuss: the system we are trying to model, the modelling approaches being used and the requirements for the design of effective integrated models Milne et al. [3]. Case studies were presented for systems in developed and developing countries, as well as urban and agricultural systems Milne et al. [3]. Modelling approaches presented included: combining different techniques into a single model (e.g. SERD) Gaube et al. [4] and Dyna-CLUE which combines a top-down and up-bottom approach Verburg and Overmars [5], neural networks Lakes et al. [6] and agent based models Fontaine and Rounsevell [7]. Integrated models were characterised as being able to model thresholds, have consistent ontology, be validated, calibrated and verified and deal should with cross-scale interactions (domain, scale and technique). Papers from the workshop were been published in a special issue of Landscape Ecology in 2009.

2.2. 'Data and model integration for coupled models of land use change'

A variety of data is required to drive integrated models of land systems. Data may be for different spatial and temporal scales and record different aspects of the land system. Using different data types and sources generates a number of issues which need to be explored. Five key issues were considered at the 'data and model integration for coupled models of land use change' workshop: data sources, using data sets of different scales, merging, scaling and aggregation, collecting data for modelling, data infrastructures and ethical issues.

Attention was given data standards, time required before a change can be detected and the time-steps chosen in data collection and the impact of scenario results based on the data processing technique used. Case studies from New Zealand and Nigeria highlighted the difficulties many land use researchers face with data collecting. Examples were also given on modelling land use at intermediate scale and issues associated with scaling up and down. The broad range of research fields of participants meant these issues could be tackled from a variety of disciplinary angles, helping to identify priorities in data and model integration for coupled models of land use change.

2.3. 'Representation of ecosystem services in the modelling of land systems'

Understanding ecosystem services is increasingly important as land planners and policy makers make land management choices. Models of ecosystem services as an integral part of land systems are needed, both to adequately capture the complex dynamics of human-environmental processes, and to explore the

consequences of land change in the provision and management of ecosystem services. The Millennium Ecosystem Assessment MEA [8] defines ecosystem services as the benefits people obtain from ecosystems. Ecosystem services are categorised as: provisioning services (e.g. food and fuel), regulatory services (e.g. climate regulation and water regulation), and cultural services (e.g. recreation and aesthetic value) and supporting services (e.g. soil formation and nutrient cycling) MEA [8].

In order to explore ecosystem services and trade-offs between them we need to be able 1) to represent and measure ecosystem services provided by land systems and 2) to relate ecosystem services not only to economic value but also to human well being. Models can provide useful tools to explore tradeoffs between services. Many tradeoffs are associated with human responses to, and use of, ecosystem services, with actions that benefit some services potentially having negative consequences for others.

International researchers drawing from their own work, came together to explore the measurement and representation of ecosystem services in land systems and models for application in policy and practice. Consideration was given to how local decision making and radical changes could be incorporated into top-down and bottom-up models and how these models could be coupled. Discussions also centred around the conflict within the scientific community on the definition and terminology of ecosystem services with case studies highlighting the challenges faced in participatory studies with perceptions of ecosystem services. Representations were made from participants who have adopted the concept of landscape functions Verburg et al. [9] and Willemen et al. [10] for their research. Modelling ecosystem services in urban regions and the potential and realised ecosystem services from landscapes were also represented.

3. Copyright

To further the promotion and support for the GLP science plan, the nodal office has also sponsored other events aimed at developing our understanding of land system models. The Agent-Based Land Market Models Workshop in 2009, co-sponsored with the US NSF-sponsored SLUCE 2 project Robinson and Brown [11], addressed a range of issues related to land market models: macro-scale drivers, institutional and policy environment, empirical implementation and special topics: auction mechanisms, developer behaviour and environmental issues.

The Agent-Based Modelling of Land Use Effects on Ecosystem Processes and Services symposium at the 2009 IALE (US) conference in Utah, considered developments in coupled human-environmental system modelling using agent-based simulation. Agent-based modelling has been applied to the study of land use and cover change by numerous researchers, but the use of agent-based models on coupled human-environmental systems remains relatively uncommon. A special issue of symposium papers is currently in press in the Journal of Land Use Science.

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